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The role of the labrum in early treatment of unstable developmental dysplasia of the hip

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- The objective of the paper is to analyse the role of the labrum with particular attention to its morphological changes in unstable dysplastic hips during treatment.
- Between January 2013 and December 2015, data were collected on 86 unstable, dysplastic hips, which were divided into type D ($n = 13$), type III ($n = 49$) and type IV ($n = 24$). The labrum was evaluated with ultrasound examination (US) for echogenicity and dimensions with inter-/intra-observer tests comparing the US images at diagnosis and at the end of treatment. Statistical analysis was performed.
- At the end of treatment of unstable, dysplastic hips, the labrum was more echogenic with a frequency of 97% and was larger with a frequency of 96%.
- The labrum has an active stabilizing role in unstable dysplastic hips and it undergoes a statistically significant increase of echogenicity and dimensions after treatment.

Keywords: acetabular labrum; early diagnosis; unstable dysplastic hip

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Introduction

The acetabular labrum or 'labrum' is a fibrocartilaginous structure which surrounds the acetabulum and contributes to the stability of the femoral head in the acetabular socket by deepening the latter and increasing the articular congruity.[1] The labrum has been considered as an obstacle to reduction in unstable and dysplastic hips. Severin in 1950, reported that it was unnecessary to excise the limbus if the arthrographic follow-up demonstrated a remodelling of the inverted limbus and a favourable maturation of the acetabulum.[2] Staheli in 1978 reported that the number of surgical procedures on a dysplastic hip was greater if an inverted limbus was present.[3] In another study, Ponseti in 1978 described the limbus as an expression of a hypertrophic labrum;[4] he reported that it was visible especially in the superior-lateral margin of the acetabulum and that it represented an important obstacle to reduction in many cases of developmental dysplasia of the hip (DDH). Fleissner in 1994, in an article regarding closed reduction of the hip, proposed an arthrographic classification in order to give an assessment of success (or lack of it) of the reduction.[5] Carlioz and Felipe, in an article in 1982, used as synonyms 'limbus' and 'labrum' and referred rather vaguely to 'limbus interposition' and 'inverted fibrocartilaginous labrum'.[6] Previously, the term 'labrum' has often been, inappropriately, confused with or substituted by 'limbus' and 'neolimbus'. In fact, the neolimbus is a 'new' fibrocartilaginous structure that forms because of the forces applied by the dislocated femoral head. This was well described by Ortolani and was demonstrated in his anatomical preparations. The limbus has also been confused with the labrum or with the acetabular cartilaginous rim or both. According to some authors, the limbus is a hypertrophic labrum, which has developed because of abnormal forces applied to it by the femoral head.[7,8]

With the development of ultrasound (US) screening programmes in the 1980s for the evaluation of hip dysplasia, the labrum acquired an increasingly important role as a landmark in Graf's classification and US technique.[9–12] The US examination allows the correct anatomical distinction of the fibrocartilaginous labrum (echogenic) from the hyaline cartilaginous acetabular rim (not echogenic) and the bony rim (very echogenic).[13]

The aim of this retrospective study was to determine the role of the labrum, by utilizing the US images present in our database for 'developmental dysplasia of the hip (DDH)' and by describing its morphological changes in unstable and dysplastic hips during treatment.

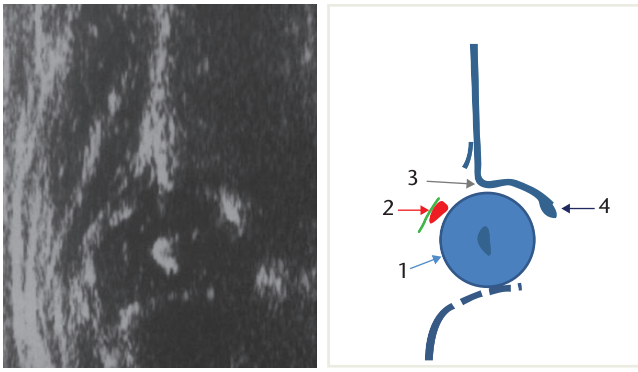

Fig. 1 An ultrasound image of a normal hip in three-month-old female. On the right side a diagram with the anatomical structures: (1) femoral head with ossific nucleus; (2) a normal triangular-shaped labrum, positioned above the femoral head and below the capsule (green 3) bony rim of the os ilium. The latter must be a straight line in order to have a standard frontal plane (fundamental for a correct image); (4) lower limb of the os ilium, a very echogenic (and large) structure.

Patients and methods

Between January 2013 and December 2015, data were collected from 60 patients (52 F; 8 M), with an age range between 1 day and 134 days (average 53 days) at DDH diagnosis and beginning of treatment, in 86 unstable and dysplastic hips (32 unilateral – 13 right hips, 19 left hips and 27 bilateral). The US examination was performed according to Graf's technique, using a Siemens Sonoline Adara with a linear 7.5 MHz probe (Fig. 1). The treatment was always performed putting the hips in squatting position (100–110° flexion, 50° abduction) (Fig. 2) without differences between the position in a cast or in a device. The average length of treatment was 18 weeks. If the hips were dislocated and needed a closed reduction, a cast was applied; otherwise, a splint was used to hold the position.

Inclusion criteria were:

(i) patients with type D, III, IV hips according to Graf's classification, therefore, by definition, 'unstable' hips;
(ii) complete US history with images: (1) at diagnosis, (2) at the end of treatment;
(iii) US examinations performed by the same certified operator.

The 86 hips were divided into type D (*n* = 13), type III (*n* = 49) and type IV (*n* = 24). This sample was further divided in two sub-groups according to the unilateral or bilateral involvement. For the evaluation of the US images in patients with a unilateral involvement, the contralateral healthy hip was used as the control image.

Fig. 2 The squatting position for treatment. The hips are flexed at 100–110° and abducted at 50°.

In patients with bilateral involvement a control group was created. The control group consisted of 50 healthy patients (100 hips), with a first diagnosis of type Ia or Ib hips, selected randomly from the database of our DDH Referral Centre. The control group was divided into five sub-groups according to age: Group 1 (age 0–30 days); Group 2 (age 31–60 days); Group 3 (age 61–90 days); Group 4 (age 91–120 days); Group 5 (121–150 days); each of these sub-groups was further divided according to gender and side. For the comparison of the US image of bilateral DDH involvement, an image from the control group was selected randomly, with respect to age, gender and side.

In the comparison of the US images, the labrum was the focus of the study. We evaluated its echogenicity and its dimensions performing an inter- and intra-observer test, with four different assessors (two paediatric orthopaedic surgeons, one radiologist and one radiology technician).

The tests were performed as follows:

(1) Test 1: comparison between an US image of the labrum at DDH diagnosis and an US image of the labrum chosen randomly, with respect to side, gender and age, from the control group (in bilateral involvement) or the contra-lateral healthy hip (in unilateral involvement).
(2) Test 2: comparison between an US image of the labrum at DDH diagnosis and an US image of the same patient at the end of treatment, on average 18 weeks after diagnosis and beginning of treatment (average age at end of treatment 8.2 months [range 2.8–15.0 months]).

Intra-observer tests were repeated after one week. Inter-observer tests were conducted separately for each operator. The qualitative scales created for the evaluation of the labrum were:

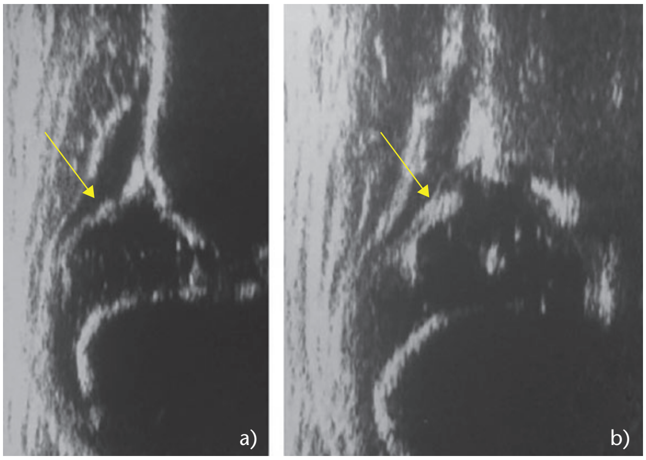

Fig. 3 (A) An ultrasound image of a type III hip in a two-week-old male; (B) the same hip (normalized) at the end of treatment (age five months). The yellow arrows indicate the position of the labrum on top of the femoral head. It is clearly visible that there is an increase in echogenicity and dimensions after treatment in Figure 3B.

- For echogenicity:
  - Greater echogenicity (+1)
  - Same echogenicity (0)
  - Lower echogenicity (–1)
- For dimensions:
  - Larger dimensions (+1)
  - Same dimensions (0)
  - Smaller dimensions (–1)

For statistical purposes, the data collected were analysed using Microsoft Excel; statistical analysis performed with SPSS. Graphs were obtained using both. Cohen's k coefficient was used to calculate the intra-observer concordance for all four operators; this coefficient is a measure of concordance between a pair of operators (in our case the same operator performs the test twice at two different times). Fleiss's k coefficient was used to calculate the inter-observer concordance between all four operators.

Results

For the statistical analysis Cohen's k coefficient was adopted and it has a range between 0 and 1.

- If k is between 0–0.2, poor concordance
- If k is between 0.21–0.4, fair concordance
- If k is between 0.41–0.6, moderate concordance
- If k is between 0.61–0.8, good concordance
- If k is between 0.81–1, excellent concordance

Table 1. Intra-observer statistical analysis according to Cohen and k values in Tests 1 and 2. Test 2 has an excellent concordance

	ECHOGENICITY	
Test	Operator	Cohen's coefficient
1	A	0.869
	B	1.000
	C	0.812
	D	0.889
2	A	0.852
	B	1.000
	C	1.000
	D	1.000

Note. A, D = pediatric orthopedic surgeons; B = radiologist; C = radiology technician.

Echogenicity

In Test 1, the most frequent categorical ordinal variable was –1 (lower echogenicity) with a frequency of 79%, implying that the labrum of an unstable dysplastic hip is frequently less echogenic with respect to a healthy comparable hip. In Test 2, the most frequent categorical ordinal variable was +1 (greater echogenicity) with a frequency of 97%, implying that the labrum of a treated unstable dysplastic hip at the end of treatment is more echogenic with respect to the same hip at DDH diagnosis (Fig. 3). The results of Cohen and Fleiss' k coefficients are described in Tables 1 and 2.

Dimensions

In Test 1, the most frequent categorical ordinal variable was –1 (smaller dimensions) with a frequency of 80%, implying that the labrum of an unstable dysplastic hip is frequently smaller with respect to a healthy comparable hip. In Test 2, the most frequent categorical ordinal variable was +1 (larger dimensions) with a frequency of 96%, implying that the labrum of a treated unstable dysplastic hip at the end of treatment is larger with respect to the same hip at DDH diagnosis (Fig. 3). The results of Cohen and Fleiss' k coefficients are described in Tables 3 and 4.

Discussion

The labrum is an interesting topic in the discussion of DDH, especially for its relationship with the femoral head. Regarding the newborn hip, the entire scientific community has been stimulated to research its role, which is still debated at the present time.[14–18] In the past, many authors have considered the labrum as an obstacle to the femoral head reduction.[4–6,19–21] In particular, Ponseti[4] described an inverted labrum in dislocated hips, based on anatomical samples of newborns at his disposal. However, he also described how in the early stages of dislocation, the labrum

Table 2. Inter-observer statistical analysis according to Fleiss and k values in Tests 1 and 2. Test 2 has an excellent concordance

ECHOGENICITY	
Test	**Fleiss' coefficient**
1	0.731
2	0.863

Table 3. Intra-observer statistical analysis according to Cohen and k values in Tests 1 and 2. Test 2 has a good/excellent concordance

	DIMENSIONS	
Test	**Operator**	**Cohen's coefficient**
1	A	0.720
	B	1.000
	C	0.675
	D	0.851
2	A	0.741
	B	1.000
	C	0.738
	D	0.828

Note. A, D = pediatric orthopedic surgeons; B = radiologist; C = radiology technician.

Table 4. Inter-observer statistical analysis according to Fleiss and k values in Tests 1 and 2. Test 2 has a good concordance

DIMENSIONS	
Test	**Fleiss' coefficient**
1	0.410
2	0.746

is atrophic, flattened and adherent to the inner aspect of the hip capsule. In these cases it is not inverted and does not participate in the formation of the acetabular ridge.[22] We confirmed these aspects (shape and position) in our study. Recent clinical experience has shown that the labrum does not represent an obstacle to reduction of the dislocated femoral head.[23–25] In a study on closed reduction in 20 dislocated hips, De Pellegrin et al never encountered an inverted labrum; the US examination was performed at an early average age of 42 days.[25] Similarly, Eberhardt et al in 2015, in an arthroscopic study, described the labrum as a fibrocartilaginous margin, which does not protrude and never represents an obstacle to reduction.[23,24] Hughes described the labrum in over 200 dislocated hips, which underwent open reduction, in older children. All these patients were studied pre-operatively with arthrography. In these dislocated hips, the labrum was described as thickened and pressed medial to the femoral head.[26] However, in newborns, if early diagnosis and treatment are applied, the labrum was always over the femoral head and not medial.[25] Although the arthrographic examination and intra-operative observation seem to validate the hypothesis that the labrum may represent an obstacle to reduction, it has to be noted that these studies,[2–6] refer to a historical period when DDH screening was exclusively clinical by Ortolani and Barlow tests and conventional X-ray was performed at six months of age. Therefore, newborns were referred to out-patient clinics at a delayed age; this may be an explanation for the role attributed to the labrum as an obstacle to reduction. In fact, in this study the labrum was never inverted when the first US was performed and probably this is due to the early age of US diagnosis (average age of our population was 53 days). Furthermore, at control US, after closed reduction and treatment, the hip was always centred and the labrum was still above the femoral head. Arthrography has always been considered the gold standard for the identification of the soft tissues between the femoral head and the acetabulum.[5,27,28] However, it gives us indirect information on these structures. In another study, Diaz[29] suggested that US might help in the evaluation of interposed soft tissues, making it a possible substitute for more invasive techniques, such as arthrography. Confirmation of this came from a study by Abril et al[30] where the authors demonstrated a significant concordance between US and arthrography for the diagnosis of an inverted labrum and of soft tissue in the acetabulum. Ultrasound is as useful and as accurate a technique in detecting the position of the labrum as arthrography. Magnetic resonance imaging (MRI) is a useful tool in patients to assess the morphology of the acetabulum. However, the MRI studies were conducted in children with an age of between three and seven years. In the literature, there is no information on structural changes in newborn hips affected by DDH, detected by MRI.[31–33] The advantage of US, other than being less invasive, is that it allows for analysis of the intrinsic structure of the labrum. In our study, the parameter 'echogenicity' was considered as a structural evaluation of the fibrocartilaginous labrum, in order to verify whether or not the latter underwent changes during treatment, recognized as a histological alteration of the cartilage of which it is constituted. The most important morphological change observed in the labrum during growth is its progressive increase of collagen fibres.[34,35] In fact, the results show a different echogenicity of the labrum in a dislocated hip at diagnosis and beginning of treatment with respect to a normal hip, as well as an increase in its echogenicity during and at the end of treatment. A statistical analysis of the comparison between the different age groups, of the morphological changes of the labrum (echogenicity and dimensions), was not conducted. This is due to the small number of patients per age group, which is a limitation of the study. However, the comparison of dimensions with respect to age would not be significant because there is a physiological growth of the labrum, so the dimensions will always be larger in older patients. Instead, the evaluation of the age-related echogenicity should be conducted with a statistical inter-/intra-observer study employing a larger number of patients.

Despite the individual morphological structure of the always-triangular-shaped labrum, the study demonstrates the lower echogenicity and dimensions of the labra in dysplastic unstable hips in comparison to the normal hips and the increased echogenicity and dimensions of the same labra at the end of treatment. Our hypothesis is that the labrum, similarly to the cartilaginous rim, constricted in a de-centred hip, becomes hypotrophic (lower echogenicity). This might be explained also by the analysis vascularization of the labrum, which is reduced by compression. A recent study by Kelly reports the existence of an internal vascular ring of the labrum, where the latter is divided into two zones: one zone closer to the articular portion (Zone II) and another zone closer to the joint capsule (Zone I). These zones are divided into more peripheral portions (Zone IA and IIA) and portions closer to the bony rim (Zone IB) and cartilaginous rim (Zone IIB). Zone IB is well vascularized and the blood supply comes mainly from the bony acetabulum. The blood supply to the more peripheral Zones IA and IIA, instead, comes from the hip capsule. Zone IIB is considered avascular.[36] Considering the results of the test, it appears that the labrum in a DDH-affected hip undergoes a statistically significant increase in echogenicity and dimensions after treatment; we assume that the absence of mechanical compression and subsequent reactive hyperaemia may be responsible for the increased dimensions during stabilizing treatment. The increase in echogenicity of the labrum, which corresponds to an increase of its fibrous component, suggests a stabilizing role, as the centred femoral head is kept in place by a 'histologically more robust' structure.

Reduction and stabilization of the femoral head, with positioning of splints or cast, does not imply the absence of articular micro-movements. The labrum should be regarded as a 'living' structure and undergoes morphological alterations during treatment. Also, different movements may stimulate its growth, detectable by US.

Test 2 showed the greatest concordance, with a 97% response for echogenicity and 96% for dimensions. We assume that the four operators have actually reported both an increase in dimensions and in echogenicity at the end of the treatment of unstable dysplastic hips.

The squatting position during treatment obviously involved the healthy contralateral hip as well; however, the results did not show any morphological changes of those normal labra, showing that the position itself was not responsible for them. The 'human' position, which is maintained spontaneously by newborns, such as in our control group, did not cause any changes of the labrum morphology.

This study is a preliminary study on the morphological changes of the labrum and has the following limitations. Firstly, the evaluation of echogenicity and dimensions is not standardized in the literature; therefore, we had to use intra- and inter-observer statistical tests. Secondly, although the operators were not all experts in the topic of discussion (i.e. one radiologist and one radiology technician), the statistical analysis of Test 2 for echogenicity, therefore an expression of the labrum's morphological modifications, was excellent for all operators. However, the analysis of Test 2 for dimensions was not excellent in all four operators. This was probably because there is a subjective definition of 'larger' and 'smaller' between the different operators and an US measurement of the dimensions is extremely challenging.

Conclusions

In conclusion, the hypothesis is that the labrum has an active stabilizing role by modifying its histological structure (greater component of fibrous tissue) and morphology (larger dimensions) during early treatment of unstable dysplastic hips and is not an obstacle to reduction in early treatment.

AUTHOR INFORMATION

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None declared.

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